THE 2009 FLC MID-CONTINENT REGION ANNUAL AWARDS
Nomination Form

Please note the specific criteria for the nominated award.

I nominate the following individual, technology, or organization for the following award (please √):

- ☐ Regional Laboratory Award
- ☐ Regional Partnership Award
- ☐ Representative of the Year Award
- ☐ STEM Mentorship Award (New Category!)
- ☒ Notable Technology Development Award
- ☐ Excellence in Technology Transfer
  Criteria is similar to FLC national award – see page 2

DESCRIPTIVE TITLE OF NOMINATED REGIONAL PARTNERSHIP

Sandia Cognitive Framework

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BASIS FOR THE NOMINATION

Machines are very literal and very brittle, whereas humans are flexible, adaptable, and able to easily make decisions despite incomplete data. Because of these differences, the interaction between humans and machines – an increasingly important part of our daily lives – can be difficult and frustrating, and sometimes leads to serious errors (such as the nuclear power plant accident at Three Mile Island) when humans misunderstand machines or communicate their intentions to machines incorrectly. Enabling machines to process information in a more human-like manner eases these tensions.

The technology applied in the Sandia Cognitive Framework (SCF) is compelling because it bridges the gap between science and operational environments by facilitating some of the most difficult problems we face in our heavily technology-dependent society. The SCF achieves this by instantiating a model of human cognition in software code that is lightweight, robust, and accurate enough to be applied to such diverse situations as Marines driving Humvees, enhancing fighter pilot training, enabling multiple expert models to find patterns that no single model or expert can find alone, and enhancing the realism of force-on-force simulations and non-player characters in serious game training environments. The SCF serves as a basis for technologies that augment human decision making – specifically, enhanced context recognition – and offers our nation a critical and improved capability to address a wide range of national security situations.

The Sandia Cognitive Framework was conceived in the context of immediately building models (applications) useful in real-world, highly dynamic, and ambiguous environments and situations. These computational models

replicate an individual's decision-making process using mathematical expressions for the recognition of situations based on patterns of cues (Figure 1). Similar frameworks' architectures are based only on a psychological literature in order to replicate laboratory experiments in psychology; our Framework's architecture is based on both psychological and physiological literatures, which enables us to capture key elements of human decision making to build deployable systems. From a theoretical cognition perspective, the SCF uses a dynamical systems based (connectionist type) approach rather than the commonly used rules-based approach; this enables the models to adapt real-time during their application (such as when operating in an ambiguous situation) and makes them more robust against the effects of overtraining than other cognitive modeling capabilities. Another important benefit of our Framework over similar technologies is that it processes orders of magnitude more data in a given period than other cognitive frameworks – for example, the maximum sampling rate for a real-time run by a leading competitor has been measured at 40-50 Hz for an instance-based approach and 500 Hz for a rule-based approach; our Framework was able to process a real-time sampling rate of several hundred thousand Hz during the same amount of time.

The Sandia Cognitive Framework has already been creatively applied to solve a variety of problems pertinent to both Government and commercial sectors. From military operators to security personnel to emergency first-responders, the SCF has proven how the decision-making skills of the humans-in-the-loop can be advanced. The number of viable commercial markets that could benefit extends from the automotive industry, to gaming, to education and medicine. Following is a sampling of SCF-related research projects that could impact such diverse Government and commercial market areas.

- **Distributed Dynamic Decision-making (DD) Airborne Warning and Control System (AWACS)** - A simulation training environment with a reasonably high level of complexity in which operators simultaneously control multiple assets and respond to multiple threats. The SCF was used to help derive an individualized cognitive model of AWACS operators with regard to situations, associated cues, and the relationships whereby patterns of cues prompted the recognition of situations.
- **Discrepancy Detection** - A machine-based cognitive model generated to provide real-time awareness of the cognitive state of an operator. Using the model, a machine can monitor its own state and identify when there is evidence of a discrepancy between the actual state of the machine and the operator's perceptions concerning the state of the machine. This project offers a successful proof that a machine may accurately infer an operator's interpretation of situations based on an individualized cognitive model of the operator.
- **Group Decision Making (Cognitive Collective)** - Simulation of effective aspects of group decision making using multiple cognitive models of diverse experts that interact with one another in a human-like manner. The output (results) of this Cognitive Collective form a more complete picture of an Insider Threat situation by detecting suspicious patterns, alerting a human operator (security officer), and recommending that investigative measures be taken to determine the cause. Thus, users interact with the Cognitive Collective as a group of advisors that offer multiple perspectives toward the (human) decision-making process. Our Cognitive Collective has proven reliable, too: it interpreted situations the same way the live human group did between 87% and 93% of the time, depending on the specific makeup of the Collective algorithms.

- **Mitigating Operator Overload and Improving Situational Awareness** - Cognitive models are automatically generated to explicitly identify implicit relationships between sensors, enabling recognition of driving contexts. These cognitive models are optimized by efficient machine-learning algorithms that approximate a human's ability to recognize potentially difficult situations. Used to mitigate operator overload and improve situational awareness for the US Marine Corps, the cognitive models have been validated and field tested, resulting in a factor of two (100%) improvement on human performance of complex tasks conducted in driving contexts.
- **Simulating Emotions for First Responders Under High Stress** – The SCF is incorporated in the Homeland Security game *Ground Truth: Toxic City*, which allows a player acting the role of an Incident Commander to interact with virtual teammate agents serving as First Responder units (fire, police, and HazMat) to evacuate an urban area from a chlorine spill (Figure 2). The agents are capable of simulating certain emotions that a first responder might experience during high-stress situations. Sandia National Laboratories developed the cognitive agents in partnership with and University of Southern California GamePipe Lab.
- **Large-scale Social Simulations** – The SCF has been incorporated into cognitive models that populate a large-scale social simulation of large-scale human interactions. These cognitive models operate within a social structure including patterns of influence and resistance, terrorist groups, criminal groups, and general social organization to produce a massively parallel simulation for a specified global conflict.

The SCF is extensible to a variety of projects requiring psychologically plausible models – that is, models that exhibit behavior at an observable/measurable level similar to what humans do – either specific to an individual or general to a certain group or culture. Thus, the future is bright for technology transfer, and Sandia is exploring a spectrum of possible applications for this versatile and broadly applicable technology, including: virtual agents within other security and non-Government modeling and simulation programs or gaming systems; neurocomputers; embedded intelligence in robotics and machines; physio-cognitive assistive and assessment technologies in medical diagnosis and remediation; and interactive immersive learning environments for educational advancements. Early successes where the SCF has been core to technologies delivered to customers with human-dimension mission applications include augmented cognition systems developed for the Defense Advanced Research Projects Agency (DARPA) and the Office of Naval Research (ONR), legal defense tools developed for the Department of Energy (DOE), and the Adaptive Leadership Training application developed for US Special Forces.

We have been fortunate to work with excellent partners throughout the development of the SCF, including: the University of Illinois; the University of New Mexico; George Mason University; Potomac Institute; Carnegie Mellon; and the University of Southern California GamePipe Laboratory.

The Sandia Cognitive Framework received a US patent entitled "Human-Machine Interaction" with application number 7,526,465 on April 28, 2009. Sandia also received a U.S. patent entitled "Simulation of Human Decision Making" with application number 7,370,023 on May 06, 2008.

ADDENDUM - GRAPHICS

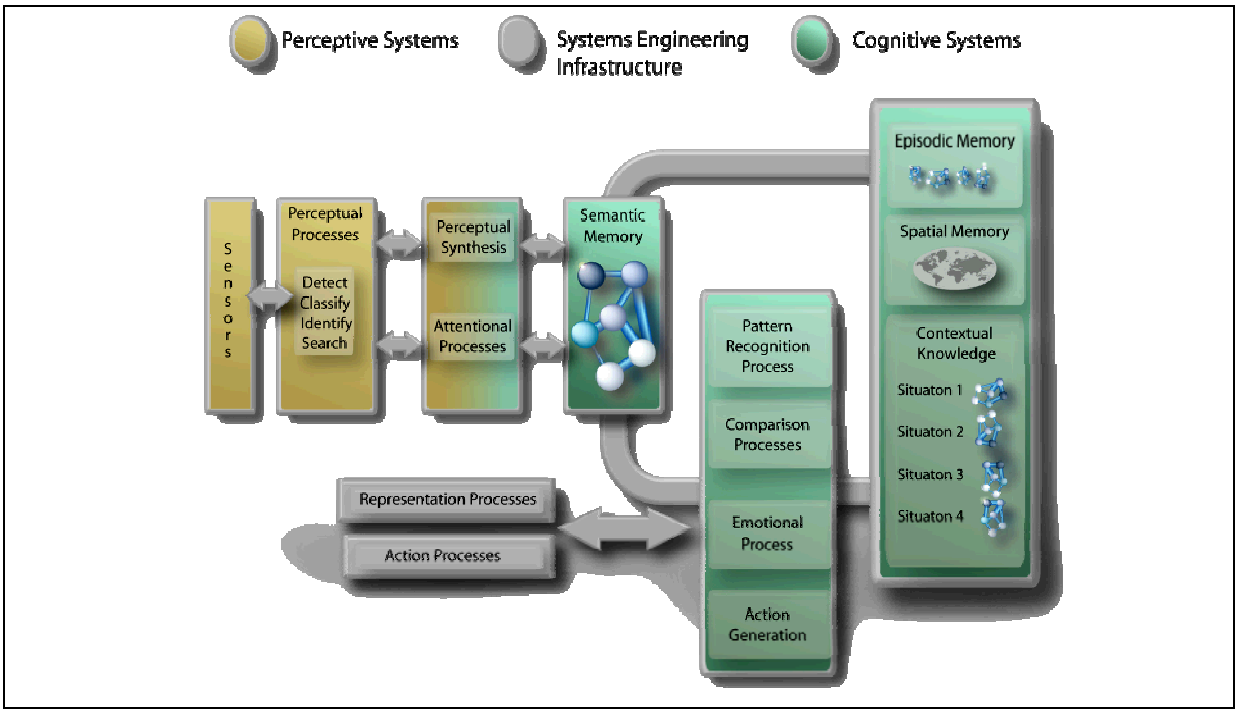

Figure 1. A Conceptual Model of the Sandia Cognitive Framework

Figure 2. Screen Shot from the Training Game *Ground Truth: Toxic City*

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